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Seven Chemicals Fail To Protect Ponderosa Pine From Armillaria Root Disease in Central Washington

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Abstract

Chemicals were applied once to the root collars of small-diameter ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) to prevent mortality caused by *Armillaria obscura* (Pers.) Herink Roll-Hansen (=*A. mellea* sensu lato). After 10 years, none of the 15 treatments appeared to reduce mortality in treated trees vs. untreated trees. Diameter growth of surviving trees averaged 3.0 millimeters per year, and the spread rate of the fungus averaged 0.6 meter per year.

Keywords: Root rot, *Armillaria*, fungus control/prevention, ponderosa pine.

Introduction

Damage in commercial conifer forests caused by *Armillaria* is widespread and can be severe in western North America (Wargo and Shaw 1985). Near Glenwood, Washington, root disease in ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) stands has been under study for the past 20 years. Research to date has concentrated on epidemiology and damage reduction (Filip and Roth 1977; Roth and others 1977, 1980; Roth and Rolph 1978; Shaw 1980; Shaw and Roth 1976; Shaw and others 1976). These and other studies show that *Armillaria* infection at the root collar of ponderosa pine, a principal host, results in mortality and that lateral root infections are much less lethal (Adams 1972, Shaw 1980).

At least two chemicals, copper sulfate (Reitsma 1932, Thomas and Raphael 1935) and iron sulfate (Gard 1925, Thomas and Raphael 1935), applied as root collar drenches, are effective in protecting trees from *Armillaria* attack. Also, several fumigants eliminate *Armillaria* from woody inoculum: these include chloropicrin (Filip and Roth 1977, Godfrey 1936), carbon disulfide (Fawcett 1925, Filip and Roth 1977), and methyl bromide (Filip and Roth 1977, Larue and others 1962). The objective of our study was to test the effectiveness of benomyl, captan, copper sulfate, iron sulfate, copper wire, vorlex, and chloropicrin in protecting the root collars of living and presumably uninfected ponderosa pine in central Washington from mortality caused by *Armillaria*.

Materials and Methods

The study area is near Glenwood, Washington, in a young-growth pine forest. The topography is flat to rolling, elevation varies from 750 to 1050 meters, and precipitation is 65 to 90 centimeters per year (table 1). Plant communities range from *Pinus ponderosa/Purshia tridentata* at the lower elevations to *Pinus ponderosa/Pseudotsuga menziesii/Carex geyeri* at the higher elevations (Franklin and Dyrness 1973). Density of understory trees more than 2.5 centimeters in diameter at 1.4 meters above ground (DBH) ranges

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from 2,500 to 5,000 trees per hectare. Site index at 100 years is moderate to good and ranges from 27 to 34 meters. Stands in the study area have been selectively harvested for the past 35 years by the Champion International (formerly St. Regis) Paper Company and the Washington State Department of Natural Resources.

A total of 180 ponderosa pine trees from 7 to 15 centimeters DBH were selected at seven locations within the study area on the basis of high exposure to infection by *Armillaria*. Probability of infection was regulated by distance from apparently advancing margins of

Table 1—Site and stand characteristics of 7 locations treated with chemical protectants, Glenwood, Washington

Location designation	Elevation	Plant community	Trees/ha > 2.5 cm DBH	Side index at 100 years
	Meters			*Meters*
A	760	*Pinus ponderosa* *Ceanothus velutinus* *Purshia tridentata*	4,940	34
B	760	*Pinus ponderosa* *Purshia tridentata*	4,075	29
C	990	*Pinus ponderosa* *Pseudotsuga menziesii* *Carex geyeri*	3,210	32
D	850	*Pinus ponderosa* *Ceanothus velutinus*	2,965	27
E	790	*Pinus ponderosa* *Ceanothus velutinus* *Purshia tridentata*	3,950	31
F	990	*Pinus ponderosa* *Pseudotsuga menziesii* *Carex geyeri*	2,470	28
G	850	*Pinus ponderosa* *Ceanothus velutinus*	3,705	27

disease centers (Shaw 1980). All selected trees were within 6.1 meters of the nearest tree showing signs of *Armillaria* infection (mycelial fans at the root collar). We selected a tree only if the total basal area of infected trees within 6.1 meters of it was between 0.009 and 0.084 square meter. This was done to standardize exposure to inoculum.

One of seven chemicals was applied once in August 1973 to each tree selected. Four of the seven chemicals (iron sulfate, copper sulfate, captan, and benomyl) were applied to a small moat (0.3 meter wide) around the root collar of each tree as a 19-liter drench. Nineteen liters of water were then added to increase percolation. Three concentrations of each material were tested (25, 50, and 100 grams of active ingredient per tree for captan and benomyl; 193, 580, and 963 grams per tree for iron and copper sulfate). Each tree treated with copper wire received 1,135 grams of wire bits (1-2 centimeters long) sprinkled around its base at the root collar zone. Chloropicrin and vorlex (80 percent chlorinated hydrocarbon, 20 percent methyl isothiocyanate) were applied to each appropriate tree in four filled and capped 132-millimeter polyethylene bottles buried 20 centimeters at cardinal points around the root collar. (Cooper (1973) demonstrated the slow release of these fumigants from such polyethylene vials.) Control trees received 38 liters of water. Treatments were assigned randomly to the trees. Each location contained some of the treatments, but not all, because of an insufficient number of candidate trees at each location. Tree mortality was monitored yearly, and diameter growth was measured on surviving trees after 10 years.

Results and Discussion

The species of *Armillaria* causing mortality within the study area was *A. obscura* (Pers.) Herink Roll-Hansen (=*A. mellea* sensu lato) or intersterility group I of Anderson and Ullrich (1979); identification was based on pairings of single-spore isolates collected within the study area (Anderson and others 1979). *A. obscura* is considered to be the most destructive species in western North America (Wargo and Shaw 1985). Ten years after application, none of the 15 treatments appeared to reduce or increase mortality in treated trees as compared to untreated trees (table 2). Differences among treatments were not tested statistically because an insufficient number of trees at all locations precluded performing a balanced, replicated design. Enhancement of *Armillaria* infection has been reported in inoculated *P. ponderosa* and *P. radiata* D. Don seedlings that were treated chemically (Filip 1976, Shaw and others 1980). Except for the first 2 years of the study, when infected trees were probably selected inadvertently, the mortality rate among the 180 trees was fairly constant at about five or six trees per year.

The diameter growth rate of trees surviving after 10 years averaged 3.0 millimeters per year (table 3). This rate is much less than the 5.0-millimeters per year diameter growth of dominant trees on each site and probably reflects the overstocked condition of the understory in many locations. Also, the growth rates of infected trees prior to being killed may have been even less, although these rates were not measured.

The spread rate of the fungus, measured annually by recording the distance of recently killed trees from apparent infection sources, averaged 0.6 meter per year (table 4). This rate is less than that reported by Shaw and Roth (1976) in the same general area, but they studied the spread of disease over several decades and among much larger trees (70-130 centimeters DBH). Chemical treatments probably did not affect the spread rate in our study because none of the treatments greatly affected tree mortality. The experimental design did not allow statistical testing of this relation.

Table 2—Incidence of ponderosa pine mortality caused by *Armillaria obscura* 10 years after treatment with chemical protectants, Glenwood, Washington

Treatment	A	B	C	D	E	F	G	All locations
	Location designation							
	Number of dead trees							
Control	6(14)[1]	1(3)	2(2)	1(2)	1(1)	0(4)	4(4)	15(30)
Benomyl:								
25 g	2(2)	1(2)	1(2)	1(1)	0(0)	1(1)	2(2)	8(10)
50 g	1(5)	0(0)	2(2)	0(1)	1(1)	0(0)	1(1)	5(10)
100 g	1(2)	0(1)	1(2)	1(3)	0(1)	0(0)	0(1)	3(10)
Captan:								
25 g	1(4)	1(1)	0(2)	1(2)	0(0)	0(0)	1(1)	4(10)
50 g	0(2)	0(1)	0(0)	2(4)	0(0)	0(2)	1(1)	3(10)
100 g	0(3)	0(0)	0(1)	0(1)	1(2)	1(1)	0(2)	2(10)
Copper sulfate:								
193 g	0(0)	2(4)	3(4)	0(2)	0(0)	0(0)	0(0)	5(10)
580 g	1(3)	0(0)	0(0)	2(5)	1(1)	1(1)	0(0)	5(10)
963 g	3(5)	1(2)	0(0)	0(1)	0(0)	0(1)	0(1)	4(10)
Iron sulfate:								
193 g	0(0)	0(2)	3(3)	1(3)	0(0)	1(2)	0(0)	5(10)
580 g	2(4)	0(1)	0(0)	1(1)	1(1)	1(1)	2(2)	7(10)
963 g	1(4)	0(1)	1(1)	2(2)	0(0)	0(0)	1(2)	5(10)
Copper wire	0(2)	0(2)	0(0)	2(3)	0(0)	1(2)	1(1)	4(10)
Vorlex	0(3)	0(0)	1(2)	3(4)	0(0)	0(0)	1(1)	5(10)
Chloropicrin	1(2)	1(1)	2(2)	1(2)	2(3)	0(0)	0(0)	7(10)
Total	19(55)	7(21)	16(23)	18(37)	7(10)	6(15)	14(19)	87(180)

[1]Number in parentheses is the total number of trees treated.

Single applications of chemicals to protect small-diameter pines from lethal infections of *A. obscura* generally are not effective, but some of the chemicals may protect pines from lethal attack in high-value areas, such as seed orchards, recreation sites, or ornamental plantings, where economics may justify more than one chemical application. More promising in commercial forests is the use of chemicals as eradicators of inoculum rather than as protectors. *A. obscura* can be eliminated from small stumps by injecting the stump with choloropicrin, volvex, vapam, methyl bromide, or carbon disulfide (Filip and Roth 1977).

Precommercial thinning rather then chemical barriers may be a better method of protecting small-diameter pines from mortality caused by *Armillaria*. Precommercial

thinning on certain sites in Oregon has significantly reduced crop-tree mortality caused by *Armillaria* (Johnson and Thompson 1975). Density of the understory on many of the Glenwood, Washington, sites is high and growth rates are low. This may predispose understory trees to infection and subsequent mortality, which could be mitigated by precommercial thinning. Current methods of control in the Glenwood area include commercial thinning with stump removal of infected pines (Roth and others 1977) and conversion to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), which is more tolerant of *Armillaria* root disease.

Table 3—Mean annual diameter increment of surviving ponderosa pine 10 years after treatment with chemical protectants, Glenwood, Washington

	Location designation							
Treatment	A	B	C	D	E	F	G	All locations
	Millimeters per year							
Control	2.8(8)[1]	1.9(2)	—	4.4(1)	—	2.3(4)	—	2.5(15)
Benomyl:								
25 g	—	8.8(1)	6.2(1)	—	—	—	—	7.5(2)
50 g	3.2(4)	—	—	4.6(1)	—	—	—	3.5(5)
100 g	3.0(1)	.9(1)	2.5(1)	8.3(2)	2.5(1)	—	4.2(1)	4.2(7)
Captan:								
25 g	3.7(3)	—	5.5(2)	.7(1)	—	—	—	3.9(6)
50 g	4.9(2)	—	—	2.3(1)	—	2.1(1)	—	3.5(4)
100 g	5.1(3)	—	2.8(1)	4.4(1)	3.9(1)	6.2(1)	1.4(2)	3.9(9)
Copper sulfate:								
193 g	—	1.2(2)	1.4(1)	3.9(3)	—	—	—	2.5(6)
580 g	1.4(2)	1.6(1)	—	4.9(3)	—	—	—	3.2(6)
963 g	.7(3)	.9(1)	—	1.4(1)	—	6.2(1)	2.1(1)	1.9(7)
Iron sulfate:								
193 g	—	1.4(3)	—	6.7(1)	—	2.3(1)	—	2.5(5)
580 g	2.5(2)	—	—	—	2.8(1)	—	1.4(1)	2.3(4)
963 g	4.2(3)	1.6(2)	—	—	—	—	2.9(1)	3.2(6)
Copper wire	3.2(2)	1.4(1)	—	4.4(1)	—	3.5(1)	—	3.2(5)
Vorlex	3.5(2)	—	—	2.5(1)	—	—	—	3.2(3)
Chloropicrin	1.6(1)	—	—	3.5(1)	3.7(1)	—	—	3.0(3)
Total	3.0(36)	2.1(14)	3.9(6)	3.7(18)	3.2(4)	2.8(9)	2.3(6)	3.0(93)

— = no living trees remaining at that location.
[1]Numbers in parentheses are the number of trees measured.

Table 4—Spread rate of *Armillaria obscura* as determined by annually recording the distance of recently killed ponderosa pine from apparent infection sources, Glenwood, Washington

Year	Location designation							Mean
	A	B	C	D	E	F	G	
	Meters per year							
1974	1.1	1.4	0.9	1.0	0.6	1.5	—	1.1
1975	.4	.9	.3	2.0	—	.8	0.9	.9
1976	.3	—	.2	—	—	—	.6	.4
1977	—	.8	.6	.5	—	—	—	.6
1978	.4	.7	.3	.1	1.1	.6	.2	.5
1979	.7	—	—	.2	—	—	1.0	.6
1980	.5	—	—	.8	—	—	.8	.7
1981	—	—	.6	.2	—	.5	.5	.5
1982	.5	—	—	.1	.5	—	.5	.4
1983	.3	—	—	.2	.4	.6	.4	.4
1984	.3	—	.4	—	.5	—	.5	.4
Mean	.5	.9	.5	.6	.6	.8	.6	.6

— = no mortality at that location for that year.

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English Equivalents

1 meter = 39.37 inches
1 square meter = 10.7639 square feet
1 centimeter = 0.3937 inch
1 millimeter = 0.0394 inch
1 hectare = 2.4710 acres
1 gram = 0.03527 ounce

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